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**Border Effects on Spatial Price Transmission between Fresh Tomato Markets in Ghana  
and Burkina-Faso: Any Case for Promoting Trans-border Trade in West Africa?**

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**Abstract**

Cross-border trade in food commodities within sub-regional economic blocks in Sub-Saharan Africa (SSA) is believed to be faster, cheaper, more convenient and welfare-enhancing than trade between SSA countries and the USA or EU. The difficulty of commodity arbitrage across borders in SSA is however a fundamental impediment to price transmission, market integration and the realisation of the welfare-enhancing role of cross-border trade. This study examines the impact of border and distance on price transmission between tomato in Ghana and Burkina-Faso. The analysis applies a linear and a regime-switching vector error correction model to estimate wholesale prices of tomato in four tomato markets in Ghana and a producer market in Burkina-Faso. The estimated parameters contain evidence of border and distance effects. This is expected since high transfer costs, including cross-border formal and non-formal tariffs are incurred by traders in moving tomato across the border. Moreover, the perishable nature of tomato, and the poor quality of roads and transportation facilities linking markets on both sides of the border imply additional risks, and constrain Just in Time delivery and price transmission from producing to retail and consuming markets. The findings have implications for interstate trade between landlocked and coastal countries in West Africa.

**Key Words:** Price Transmission, Border, Tomato, Ghana, Burkina-Faso  
**JEL Codes:** C32, Q11, Q13, Q17, Q18

## **1. Introduction**

Agricultural trade, especially trade in primary food products, in many developing countries is undergoing a tremendous, directional shift. The old trading order is characterised by the conventional exports of raw material and primary food staples from developing countries overseas to markets in countries with which the former have colonial and/or historical trade links; and conversely imports of finished products from the latter to the developing countries. The emerging trade patterns tend to embrace interstate and intra-regional trade within economic blocks and aims at improving sub-regional supply chains and meeting regional development partnership agreements. The ongoing process of globalisation and domestic market reforms under WTO establishments even appears to have assumed diminished importance under this new trading pattern.

The new trend comes not as a surprise to many economic analysts. Global developments show that with the deadlock on the WTO Doha Round of negotiations, the agricultural sectors of many low income WTO member countries are left opened to the vagaries of global economic shocks. The agricultural sectors of Sub-Sahara African (SSA) countries have particularly become extremely susceptible to external shocks from the recent world economic and food price crises. The crises-related effects on agricultural markets in SSA countries have been compounded by the increasing need for high product quality standards, rigorous sanitary and phytosanitary norms and changing demand in the markets of SSA's traditional trading partners. This has motivated a progression at varying stages by SSA countries to embrace the intra-regional distribution of goods from surplus to deficit countries.

While the changing scenario of intra-regional agricultural trading systems is unabated, it is unclear how successful this new system of trade will be. The question is does the new system offer great opportunities for the agricultural sectors of developing countries or does it represent a likely case in which the production and exports of developing countries have become more vulnerable to the risks and uncertainties of regionalism. Whatever the case may be, what is clear is the fact that the future of the new system will largely depend on incentives for cross-border trade, including efficient price transmission (PT) and market integration between intra-regional trading partners.

The transmission of price signals between spatially separated markets plays an important role in explaining market performance, their degree of integration or isolation, and the speed at which these signals are transmitted between surplus, producer markets and deficit, consumer markets for a given commodity. This is useful in guiding production and consumption decisions, and in stimulating the inter- and intra-regional trade flows needed to buffer the price and welfare effects of local supply and demand shocks (von Cramon-Taubadel and Ihle, 2009). If no barriers to trade exist, the dynamic interactions between prices of a given commodity at geographically separated locations should be so strongly linked that price shocks in individual markets within a given country evoke responses in the corresponding markets of its trading partners.

The seasonal arbitrage of fresh tomato between Ghana and her northern neighbour Burkina-Faso represents one of the largest and strongest interstate trade in agricultural commodities in

West Africa<sup>1</sup>. Between January and June yearly, about 35,000 tonnes of fresh tomato are imported from Burkina-Faso into Ghana via the arbitrage activities of itinerary female traders called *market queens* (IRIN Africa, 2009)<sup>2</sup>. While there exists trade flows of tomato across the border of the two countries to Ghana because of the absence of formal trade restrictions, the international border between the two countries nonetheless imposes some transaction costs in the form of tariffs, arbitrage delays, corruption and harassment of traders by border officials, the cost of volatile exchange rates and communication barriers between Ghanaian traders and Burkinabe tomato producers. This means, tomato price formation in Ghana's markets between January and June annually is determined not only by demand-supply shocks in Ghana and Burkina-Faso, but also by the above listed microdrivers of trade, which may culminate in appreciable levels of transaction costs and delays for haulage trucks to achieve Just in Time (JIT) delivery to retail and consuming markets.

Most empirical research on spatial, vertical or temporal price relationships in agricultural markets tends to examine the underlying factors likely to drive arbitrage, price transmission and integration between markets. For example, von Cramon-Taubadel (1998), Abdulai (2000), Meyer and von Cramon-Taubadel (2004) test the implications of market power on asymmetric price transmission in selected markets in Germany and Ghana. Moser et al (2006) examine the role of crime rate, remoteness and lack of information in the sub-regional integration of rice markets in Madagascar. Recently, Jensen (2007) and Aker (2008) shed light on the importance of information flow on stochastic price processes in spatially separated markets in India and Niger respectively. Stephens et al. (2008) and Ihle et al (2010) also examine the possibility of mechanisms, other than physical trade flow, causing stochastic price adjustments in periods during which no direct trade takes place between spatially separated markets in Zimbabwe and Ghana.

Whereas the above studies, among others, immensely contribute to our understanding of the performance of agricultural commodity markets, their common limitation include the failure to consider the existence of political impediments such as regional or national borders to arbitrage and to the spatial or dynamic interactions between prices of a given commodity in markets across countries. This study intends to add to our understanding of price transmission by extending the analysis to examine whether or not price transmission between fresh tomato markets in Ghana and Burkina-Faso displays evidence of distance and border effects. We fundamentally seek to decompose price dynamics in Ghanaian tomato markets into price transmission in the season of tomato imports from Po in Burkina-Faso to Ghana (hereafter called the Po regime) and that in the season of locally supplied tomato from Techiman in Ghana (hereafter called the Techiman regime).

Specifically, we intend to address the following objectives:

- 1) To determine the cross-country speed of price transmission (adjustment) and price transmission half-lives between four, major fresh tomato markets – Accra, Kumasi, Tamale and Techiman in Ghana and Po in Burkina-Faso when the two seasonally-switching, supply regimes are unaccounted for.
- 2) To determine the speed of price transmission and half-lives between the four Ghanaian tomato markets and Po under the Po and Techiman regimes distinctively.

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<sup>1</sup> In fact, fresh tomato and livestock (cattle, sheep and goats) are the major commodities formally traded between Ghana and Burkina-Faso, with Ghana being the importing country for both commodities.

<sup>2</sup> This is only the recorded volume of trade; the non-recorded component may be as high.

- 3) To check whether the distance and international border between the Ghanaian markets and Po matter for price transmission by comparing the estimated price transmission parameters and half-lives across the regimes.

With respect to the above objectives, the main analysis is performed first by using a standard vector error correction model (VECM) which does not differentiate between supply regimes, and second under two major, seasonally depended, tomato supply regimes – the Po regime of fresh tomato imports from Burkina-Faso to Ghanaian markets from January to May, and the Techiman regime in which fresh tomato is locally supplied in Ghana from June to December yearly. The second analysis employs a regime-dependent vector error correction model (RVECM). The data for the analysis is a semi-weekly, wholesale level dataset of prices from Po and Techiman as tomato-producing markets and Tamale, Kumasi and Accra as tomato consuming markets.

Our task is to quantify the degree of inter-market price adjustment; hence market integration, subject to regime disparities in fresh tomato supply levels, trade flows, prices and transaction costs between the selected Ghanaian tomato markets connected by trade to production area - Po in Burkina-Faso. In this way, our analysis is spatiotemporal in nature since it examines price transmission across space (market locations) and over time (season-to-season). The estimated parameters are therefore expected to serve explicitly as indicators of border and distance effects and implicitly as seasonal impacts on the integration of the markets under study.

In either way, the findings may to be applied in evaluating the potential of interstate trade in agricultural commodities within the Economic Community of West African States (ECOWAS). In this way, the findings may inform current and future policy strategies for promoting sub-regional trade, market integration and efficiency. In addition, identifying how inter-market price relationships for tomato in Ghana deviate with and without imports from Burkina-Faso may be useful in formulating policy options for tackling the price volatilities (alternating seasonal gluts and price hikes) in Ghanaian tomato markets, and for engaging in the ECOWAS protocol for free flow of people and goods in the West African sub-region. In the long run, this will guide policy towards improving the welfare of actors, viz. producers, traders, transporters and consumers in exporting and importing countries in the tomato industry in the ECOWAS sub-region.

In the next section, the paper briefly reviews the relevant literature for the study. In section three, the study area and data used for the analysis are described, while both the standard VECM and RVECM are specified and their suitability for applying them to the dataset are stated in section 4. In section 5 we present and discuss the findings, and finally draw the conclusions to the study and suggest its implications for policy and further research in section 6.

## **2. Literature Review**

Many empirical studies have often endeavoured to attribute the degree of inter-market price relationships over time (inter-temporal PT), along value-added product lines (vertical PT) or over space (spatial PT) to fundamental market- and price-related factors or variables, called the “forcing variables” of market integration (Padilla-Bernal et al, 2003).

It is generally agreed among economists that free trade promotes an efficient allocation of resources, and that tariffs and non-tariffs policies or physical market structures that impede trade reduce a country's standard of living. It has also been revealed that trade contributes to economic growth (Frankel and Romer 1999; Feyrer, 2008) and economic growth is a key determinant of welfare. Debate continues, however, on the degree to which distance and international borders as physical structures situated within the environment of officially operative sub-regional, free trade policies affect price transmission between and the integration of markets across countries sharing a common border. Therefore, understanding the impact of border effects on the performance of cross-border markets for a homogeneous commodity, especially food staples cannot be underestimated.

Fundamentally, the existence of a border between a pair of markets has two implications *ceteris paribus* for the transmission of price signals between the market pair: 1) a minimal effect due to efficient arbitrage activities and a free flow of the commodity and market information over space (such as in a functioning trade zone with a common currency and low or zero tariffs), or 2) varying degrees of negative effects resulting from tariff and non-tariff measures, border formalities and costs due to corruption, collusive behaviour of traders etc (Ihle, von Cramon-Taubadel and Zorya, 2010). The second effect is likely to be the case for commodities with a low inter-temporal (harvest-delivery) gap such as fruits and vegetables; and in developing countries where storage (mechanical refrigeration) and processing facilities for extending the inter-temporal period are lacking, and the impediments mentioned above exist.

Goodwin et al (2002) associate price transmission between markets with improvements in transportation and telecommunication, factors which boost the connectivity of buyers to sellers and reduce commodity or buyer search costs. According to Barrett (2001), the observance of trade flows between markets is important for their integration and efficiency. In fact, increased trade flows between markets may imply increased integration and equilibrium between them (Padilla-Bernal et al, 2003).

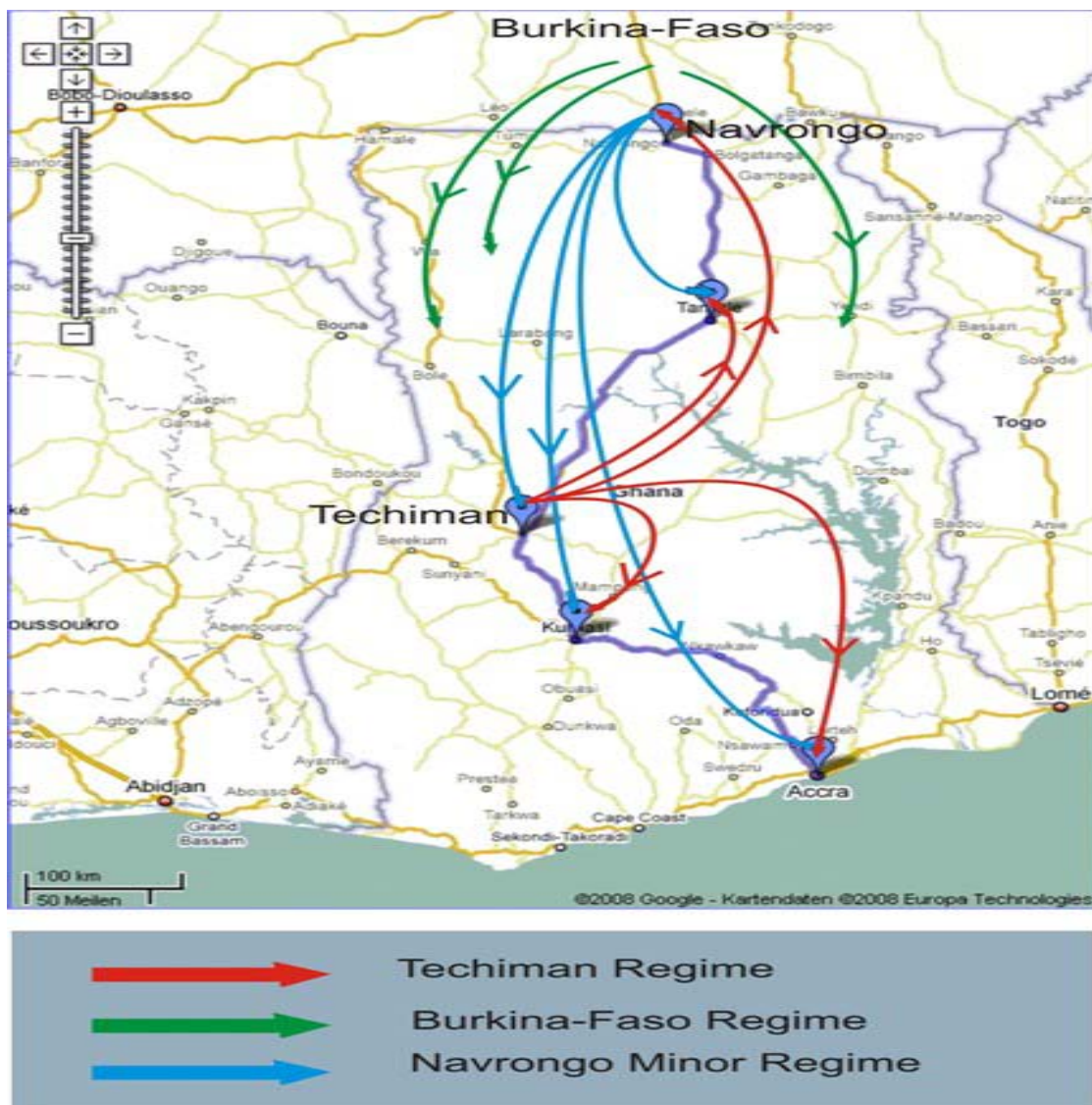
Miljkovic (1999) in Padilla-Bernal et al (2003) identify several reasons that often explain lack of integration between markets, namely noncontinuous trade flows, pricing to market, and the geographical separation of markets. Ankomah, 2011 identify increases in waiting time for haulage trucks and constraints to JIT delivery to retailers and consumers in areas of deficit production to be an important determinant of market performance. A few studies in the literature also measure price adjustment parameters subject to seasonal shifts in output and prices (Parrott et al, 2001; Goodwin et al 2002 and Goetz and von Cramon-Taubadel, 2006).

All these studies determine different responses emanating from different levels of shocks associated with the underlying determinants or "forcing variables" of price transmission and market integration viz. transaction costs, thresholds, trade and information flows, distance etc. These studies, unlike ours, however either focus on non-perishable commodities or are based in temperate, industrial countries where political (border) impediments to arbitrage and limitations to storage/mechanized refrigeration and processing are minimal. Our study in this regard is therefore a unique addition to the price transmission literature.

### 3. Study Setting and Dataset

Four major, Ghanaian tomato markets – Accra, Kumasi, Techiman and Tamale, and a key production centre - Po in the Central Province of the Republic of Burkina-Faso are considered under the analysis. The Ghanaian tomato markets include one net producer market - Techiman which supplies a substantial share of Ghana's fresh tomato in the rainy season – June to December, and three net consumer markets namely Tamale, Kumasi and Accra located in the three largest cities of Ghana. The markets under study and the pattern of trade flows between them are depicted in Figure 1.

**Fig.1: Map of Ghana showing the Markets and Pattern of Seasonal Trade Flow**



Due primarily to differences in the weather conditions between Ghana's major producer market – Techiman and that of Burkina-Faso – Po, fresh tomato supply to the Ghanaian tomato market is seasonally-switching. The producer market in Po is located in the Sudan Savannah climatic zone and is dependent on irrigated production. It is a prominent source of tomato supply, contributing about 60% of the total demand of fresh tomato to the Ghanaian market in the dry season (December - May). Techiman (and surrounding areas) located in the

southern, forest region of Ghana, using a rain-fed production system, supplies the marketing system with tomato in the rainy season (June- December). Alongside the Po supply season is another major supply and trade flow regime – Navrongo, which supplies an estimated 40% of fresh tomato within the dry season.

From the above description, three trading regimes can be identified in Ghana’s tomato marketing system in terms of supply and trade flows, namely the Navrongo and Techiman regimes with domestic sources of supply, and the Po regime representing fresh tomato imports from Burkina-Faso. Table 1 presents the mean values and standard deviations of each of the price series under the analysis for the Po and Techiman regimes.

**Table1: Regime-Dependent Average and Standard Deviation of the Price Series (GH¢/Crate)<sup>3</sup>**

| <i>Market</i> | <i>Po Regime</i> |                    | <i>Techiman Regime</i> |                    |
|---------------|------------------|--------------------|------------------------|--------------------|
|               | <b>Mean</b>      | <b>Stand. Dev.</b> | <b>Mean</b>            | <b>Stand. Dev.</b> |
| Po            | 61.21            | 39.92              | 50.35                  | 28.37              |
| Tamale        | 64.36            | 72.96              | 37.27                  | 17.67              |
| Techiman      | 58.65            | 32.29              | 37.14                  | 23.08              |
| Kumasi        | 62.37            | 24.25              | 44.82                  | 22.44              |
| Accra         | 98.95            | 62.25              | 73.42                  | 40.06              |

Source: Author’s Own.

Examining the mean and the standard deviation values of the price series under each regime in Table 1, it can be observed that in the overall, the mean values ranging from about GH¢59.00 to about GH¢99.00, and the standard deviations ranging from GH¢24.00 to GH¢73.00 for the price series under the Po regime are higher than the corresponding values ranging from GH¢37.00 to GH¢73.00 and GH¢18.00 to GH¢40.00 respectively under the Techiman regime. The regime-disparities in the descriptive statistics computed above may influence dynamic price adjustment processes between the markets under study.

It should be noted that there are never wholly exclusive delimitations defining each of the three regimes and alternating supply regimes may exhibit common points of convergence. Our definitions here depend on the patterns of supply from the production areas, while observing that the length of regimes may vary with supply patterns, which in turn may be seasonally determined. The near-periodicity in the occurrence of the supply patterns nevertheless provides a practical basis for our classification of the trading regimes as defined above.

From the above description, we hypothesized that border and distance effects do influence the integration of the markets under study. We expect these effects to delineate the inter-market arbitrage processes into two principal regimes, defined by the sources of tomato supply and trade flow. These, as defined above, are the domestic, Techiman regime and the cross-border

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<sup>3</sup> Since the Navrongo regime supplies just about 40% of usually a lower quality fresh tomato, and occurs simultaneously with and is geographically proximate to the Po regime; and since our interest is to examine within-country and cross-border price transmission processes in distinct supply regimes, we drop Navrongo and use only the Techiman and Po regimes in the analysis.

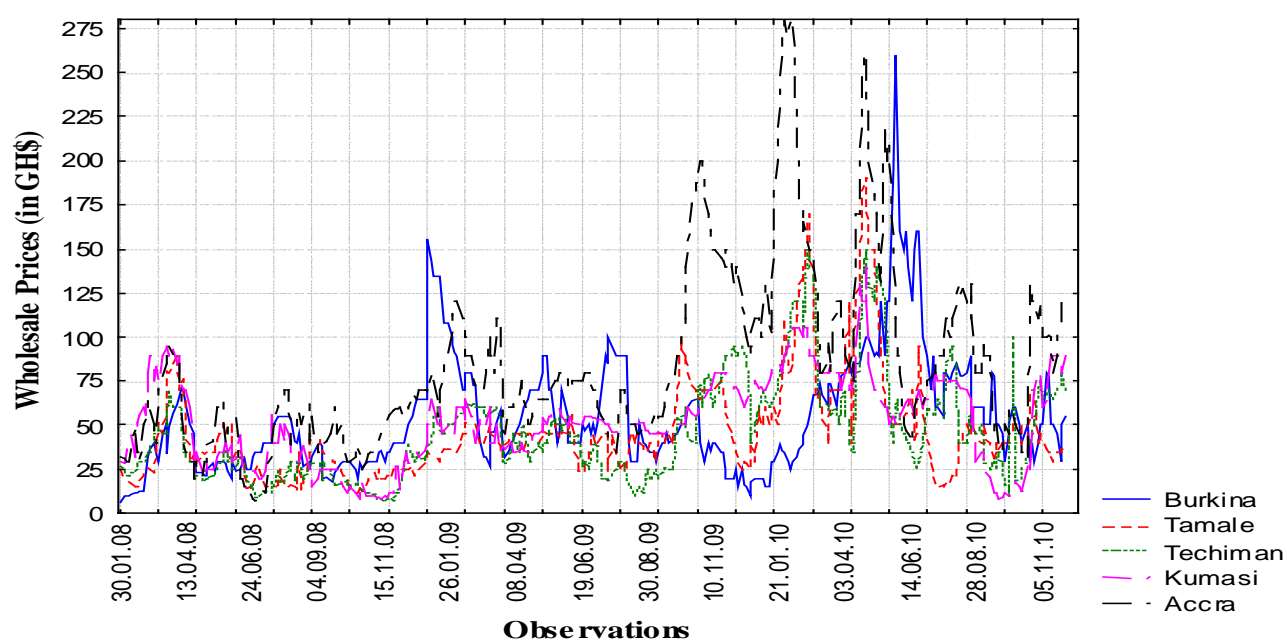


Po regime. That is, changing supply levels from the two sources act as shocks to market equilibrium and solicit different responses, depending on the patterns of trade flow and switching in the source of supply as illustrated in Fig. 1.

The complete data used for the analysis comprises a two-year long (spanning four tomato production seasons), semi-weekly, wholesale level price series from 1.2008 and to 12.2010 with 348 observations. The series is generated through self-conducted market surveys administered continuously for the four tomato production seasons in the five tomato markets – Po, Tamale, Techiman, Kumasi and Accra. The prices are those observed for the best quality of tomato available at each point of the survey in the given markets.

Though the survey yields data comprising wholesale level prices, trade flows, transaction costs and other descriptive information on fresh tomato markets in Ghana, only the price series, expressed in nominal terms of the new Ghana Cedi (*GH¢*) per a maxi-crate of fresh and ripped tomato, is explicitly used in this analysis. The additional information however provides a context for discussing and drawing conclusion from the empirical results. Fig. 2 depicts a graphical plot of the five price series.

**Fig. 2: Wholesale Level, Semi-Weekly Prices of Fresh Tomato in Ghana and Burkina-Faso (1.2008 - 9.2010)**



Source: Author's Own

The graphical analysis of fresh tomato prices in the five markets show the normal pattern of variability pertaining to prices of perishable commodities. It appears that the markets of Kumasi, Techiman, Tamale and Po represent price series that are very much related in terms of co-movement. Whereas Accra follows a similar variability pattern for much of the time in the period of the analysis, fresh tomato prices in Accra tend to largely lead the rests of the prices over the entire period of the analysis. This is expected since Accra is the largest consumer market for fresh tomato in Ghana, while its farthest location (longest distance) from the domestic and cross-border production centres implies higher transaction costs and arbitrage risks, major components of the price for perishable commodities in Sub-Sahara Africa. These features theoretically represent trade and price transmission impediments between Accra and the producer markets.



#### 4. Methodology

The main model applied to analyse our high frequency data is the vector error correction model (VECM) which focuses on prices and trade regimes instead of price margins and transaction costs like the threshold autoregressive (TAR) models. Two variants of this model are used – the standard VECM and the regime-dependent VECM. We first estimate the standard VECM which does not account for regime disparities in estimating the price dynamics. Then we estimate the regime-dependent VECM which decomposes price adjustment parameters into dynamic reactions of prices to deviations from long-run equilibrium for periods with and without tomato imports from Burkina-Faso. In this way, we obtained evidence on the nature of price transmission in the absence of direct, physical trade flows of fresh tomato from Burkina-Faso to Ghana and in the presence of same. To support our findings from the RVECM, In this section, we present the theoretical framework of the VECM and specify the variants of the VECM applied to our analysis.

If the prices on the net producer market  $s$  and the net consumer market  $c$  have a long-run relationship between them i.e. they are cointegrated, we may denote the equilibrium relationship between the net consumer prices series  $P_t^c$  and net producer price series  $P_t^s$  as:  $P_t^c - \beta_1 P_t^s - \beta_0 = v_t$ . If  $v_t$ , the error term, is assumed to follow an autoregressive (AR) process, then  $v_t = \alpha v_{t-1} + \varepsilon_t$ . This means the equilibrium relationship between  $P_t^c$  and  $P_t^s$  can be expressed as:

$$P_t^c - \beta_1 P_t^s - \beta_0 = \alpha v_{t-1} + \varepsilon_t \quad (1)$$

##### *The Standard VECM*

The equation (1) implies that the long run cointegration relationship between  $P_t^c$  and  $P_t^s$  is a function of the autoregressive process  $v_{t-1}$ . In the above linear representation,  $v_{t-1}$  represents deviations from long run equilibrium, and is called the error correction term (ECT), while  $\alpha$  measures the response of  $P_t^c$  and  $P_t^s$  to deviation from equilibrium following random shocks to the markets. The  $\alpha$  is formally called the loading coefficient<sup>4</sup> or speed of price adjustment (Lütkepohl and Krätzig, 2004). We derive the standard VECM from equation (1) by specifying changes in each of the contemporaneous prices,  $\Delta P_t^c$  and  $\Delta P_t^s$ , as a function of the lagged short term reactions of both prices,  $\Delta P_{t-k}^c$  and  $\Delta P_{t-k}^s$ , and their deviations from equilibrium at period  $t-1$  (i.e.  $ECT_{t-1}$ ) as follows:

$$\begin{aligned} \Delta P_t^c &= \delta_1 + \alpha^c [ECT_{t-1}] + \sum \beta_k^c \Delta P_{t-k}^c + \sum \beta_k^{cs} \Delta P_{t-1}^s + \varepsilon_t^c \\ \Delta P_t^s &= \delta_2 + \alpha^s [ECT_{t-1}] + \sum \beta_k^{sc} \Delta P_{t-k}^c + \sum \beta_k^s \Delta P_{t-1}^s + \varepsilon_t^s \end{aligned} \quad (2)$$

Where  $\Delta P_t = (\Delta P_t^c \ \Delta P_t^s)'$  is a vector of first differences of prices in the markets  $c$  and  $s$ ; the  $\beta_k$ ,  $k = 1, \dots, n$ , are  $(2 \times 2)$  matrix of coefficients quantifying the intensity of the response of the

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<sup>4</sup> This is because  $\alpha$  contains some weights attached to the cointegration relationship in the individual equations of the VECM and determines if the cointegration relationship enters the equations significantly. For instance, a loading coefficient with a t-value  $\geq 2$  implies the cointegration relationship is an important term in the VECM equations

contemporaneous price differences to their lagged values i.e., they express the short-run reactions of the matrix of prices  $\mathbf{P}_t$  to random shocks, and  $\varepsilon_t$  is assumed to be a white noise error term. The two equations in (2) can be generally reformulated as:

$$\Delta \mathbf{P}_t = \boldsymbol{\alpha}_0 + \boldsymbol{\alpha}_1 \mathbf{ECT}_t + \sum_{i=1}^k \boldsymbol{\Gamma}_i \Delta \mathbf{P}_{t-1} + \varepsilon_t \quad (3)$$

Where  $\boldsymbol{\Gamma}_i$ ,  $i = 1 \dots k$ , is a  $k \times k$  matrix of short run coefficients ( $\boldsymbol{\beta}_k$ ) with  $k = 2$  in our pair-wise analysis. The error correction term,  $\mathbf{ECT}_t$ , so named because it depicts deviations from the long run relationship or ‘errors’ that are ‘corrected’ by the price transmission process, is a continuous and linear function of the deviation of  $\mathbf{P}_t$  from the long-run equilibrium relationship following a shock on  $P_t^s$  or  $P_t^c$ ; the  $\boldsymbol{\alpha}_0$  denotes long-run inter-market price margins. The loading coefficient  $\boldsymbol{\alpha}_1 = (\alpha^s, \alpha^c)$  are the elasticity of price transmission or the speeds of price adjustment by the net producer and net consumer markets respectively, to deviations from long-run equilibrium. The closer a value of  $\boldsymbol{\alpha}$  approaches one in absolute terms; the faster the deviations from equilibrium become corrected.

### *The regime-dependent VECM*

The regime-dependent VECM, unlike its linear form above, is specified to distinguish between unique price adjustment behaviour in periods with or without fresh tomato imports from Burkina-Faso to Ghana. As stated in section 3, switching between the two principal sources of fresh tomato supply to Ghanaian markets – Po and Techiman, occurs seasonally. The RVECM is therefore used to establish whether the degree of price transmission between Po and Ghana’s tomato markets under study differs across the specified regimes. We do this by estimating pair-wise the speed of price transmission between each of the producer markets and the consumer markets.

Using information on trade flows contained in our dataset, we specify, following Ihle et al, 2010, an indicator variable  $q_t^{cs}$  for tomato imports via the indicator function  $I_t^{cs} = \mathbf{I}(q_t^{cs})$ . The  $q_t^{cs}$  which denotes the quantity of imports equals 1 if imports of tomato from Po to the markets in Ghana occurs i.e.  $q_t^{cs} > 0$ , and 0 if no imports between Po and the Ghanaian tomato markets occurs i.e.  $q_t^{cs} \leq 0$ .<sup>5</sup> This means we assume a stable long run equilibrium relationship that distinguishes between imports (the Po regime) and no-imports (the Techiman regime), and specify the following model:

$$\Delta \mathbf{P}_t = \boldsymbol{\alpha}_1 \mathbf{ECT}_{t-1}^{Po} I_t^{cs} + \boldsymbol{\alpha}_2 \mathbf{ECT}_{t-1}^{Techiman} (1 - I_t^{cs}) + \sum_{i=1}^k \boldsymbol{\Gamma}_i \Delta \mathbf{P}_{t-1} + \varepsilon_t \quad (4)$$

Where  $\mathbf{ECT}_t^i$  ( $i \approx$  imports and no-imports or the Po and Techiman regimes) again denotes the error correction term,  $\alpha_1$  measures the speed of price adjustment under the Po regime and  $\alpha_2$  measures the

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<sup>5</sup> A reversal in direction of trade with imports flowing from Ghana to Burkina-Faso instead of the current pattern is theoretically possible.

speed of price adjustment under the Techiman regime. All other notations are as defined under the standard VECM. It can be seen that model (4) is an extension of (3), with the error correction term in (4) specified to behave differently under periods of imports (direct trade between Burkina-Faso and Ghana) and no-imports (local supply within Ghana/from Techiman). To emphasise, this varying behaviour of price adjustment under the two supply patterns constitutes two regimes – the Po and Techiman regimes.

Having pointed out earlier that transaction costs and trade flow reversal are the two most important determinants of price dynamics in the markets under study, models that are capable of accounting for both regime switching like the RVECM would be the most ideal for analyzing price transmission in the markets.

## 5. Results and Discussion

### 5.1 Unit Root and Cointegration Tests

Following the traditional approach of time series analysis, we first test for a random walk or stationarity in the individual price series by hypothesising unit roots in the levels and first differences of each price series using the KPSS test. We estimate the random walk with only a drift but without a trend because visually examining the graphical plot of the series in Figures 2 reveals the unlikelihood of a non-zero expected mean in the levels of the series. The plots however show no obvious persistent trending behaviour in the data. Therefore, we omit a deterministic trend but include a drift in both the KPSS test for unit roots and in the Johansen's test for cointegration. The chosen lag lengths in both tests are based on the Akaike Information Criterion (AIC). The results of the unit root test are presented in Table 2.

**Table 2: Results of KPSS Unit Root Tests on the Price Series**

| <i>Series</i> | <i>Test Statistics (Levels)</i> |                    | <i>Test Statistics (First Diff.)</i> |                    |
|---------------|---------------------------------|--------------------|--------------------------------------|--------------------|
|               | <b>Statistic</b>                | <b>No. of Lags</b> | <b>Statistic</b>                     | <b>No. of Lags</b> |
| Po            | 1.412**                         | 4                  | 0.102                                | 4                  |
| Tamale        | 1.969**                         | 4                  | 0.025                                | 4                  |
| Techiman      | 2.134**                         | 4                  | 0.024                                | 4                  |
| Kumasi        | 1.341**                         | 4                  | 0.035                                | 4                  |
| Accra         | 2.890**                         | 4                  | 0.017                                | 4                  |

Source: Author's Own

The asterisks \*\* and \* denote rejection of the null hypothesis at the 1% and 5% significance levels. The respective critical values at the 1% and 5% significance levels are 0.347 and 0.463 for both the test at the levels and first difference of the series. The lag value of 4 is a suitable choice.

From the above unit root results, we strongly reject the null hypothesis of no unit roots (i.e. the series is stationary) in the level of the prices series at the 1% and 5% significant levels, but cannot reject the null hypothesis of no unit roots at the first difference of the price series.

Therefore, the series under study are (first) difference stationary processes i.e. they have unit root or are I (1). Put differently, fresh tomato prices in the markets under study can be said to be non-stationary in their levels but stationary in their first differences.

With the proof from the univariate analysis that the price series are non-stationary in their levels, we proceed to test for cointegration between the net producer/net consumer market pairs using the Johansen's, maximum likelihood VAR approach. The results of the cointegration test between the market pairs are presented in Table 3.

**Table 3: Johansen's Test of Cointegration**

| <i>Market Pair</i> | <i>Test Statistic (Trace Test)</i> |                  |                    |
|--------------------|------------------------------------|------------------|--------------------|
|                    | <b>Ho: r = 0</b>                   | <b>Ho: r = 1</b> | <b>No. of Lags</b> |
| Po - Accra         | 26.40**                            | 11.14*           | 2                  |
| Po - Kumasi        | 22.49**                            | 6.46             | 2                  |
| Po – Techiman      | 27.76*                             | 8.84             | 1                  |
| Po - Tamale        | 36.50**                            | 13.58*           | 1                  |
| Techiman -Accra    | 56.34**                            | 7.74             | 1                  |
| Techiman -Kumasi   | 34.75**                            | 6.01             | 1                  |
| Techiman -Tamale   | 32.63**                            | 8.74             | 1                  |

Source: Own

The asterisks \*\* and \* denote rejection of the null hypothesis of no cointegration vector at the 1% and 5% levels respectively. The critical values for  $r = 0$  and  $r = 1$  at the 1% and 5% significance levels are 24.69 and 12.53 and 20.16 and 9.14 respectively.

The results provide evidence in favour of cointegration between the tomato market pairs under study. The null hypothesis of  $r = 0$ , implying an absence of a cointegration relationship between the producer and consumer markets is rejected for all the market pairs at both the 1% and 5% significance levels. We cannot however reject the null hypothesis of one cointegrating relation, i.e.  $r = 1$  between pairs of net producer/net consumer markets, especially at the 5% significance level. This means, there exists at least one stationary cointegration relation ( $r = 1$ ) between the pairs of net producer and net consumer price series measured semi-weekly, and by implication in the tomato marketing system under study.

The findings imply that the series have a particularly strong link that is of interest from the economic point of view. It may be because similar stochastic processes, possibly induced by efficient information flow or seasonal effects, drive the behaviour of prices in the system of markets (Motamed et al, 2008). Therefore tomato prices in the producer and consumer markets do not drift apart in the long run. The proof of cointegration is also evidence for a common interstate tomato market between Burkina-Faso and Ghana, where inter-market prices adjust to achieve long-run, market equilibrium. Perhaps the seasonal nature of tomato production, with either the Po/Navrongo or Techiman market being a major source of supply to the other markets in the system per season, the effective network of traders between producer and consumers markets and recent improvements in roads, means of transportation and information flow via mobile phones, explains this outcome. Whatever the case may be, the evidence of at

least one cointegrating relation between the market pairs provides an ideal setting for us to use the VECM to explore border and distance effects on price transmission and market integration between the selected markets.

## 5.2 Results of the Vector Error Correction Models

Having significant cointegrating vectors between the net producer and net consumer tomato market pairs is a necessary condition for using the VECM to determine the effects of price shocks on price adjustment. In this section, the results of the estimated standard VECM and the regime-dependent VECM are presented and their implications discussed. Both models are estimated by means of the reduced rank estimation procedure.

### 5.2.1 Results of the Standard VECM

The results of the econometric estimation of the standard VECM which does not account for regime disparities are presented in Table 4. The Table shows estimated speeds of price transmission and their corresponding half-lives for market pairs involving Po/Techiman and Accra, Kumasi and Tamale. Two forms of the speed of price transmission (adjustment) parameter are estimated in each VECM equation -  $\alpha^s$  which measures the response to price shocks by the producer market Po/Techiman to correct disequilibrium and  $\alpha^c$  measuring the price adjustment by the consumer markets to correct disequilibrium following shocks. The two parameters represent the dynamic interactions between Po/Techiman and Accra, Kumasi and Tamale pair-wise for the entire period of the study. The price adjustment half-lives  $\lambda^s$  and  $\lambda^c$ , for the producer and consumer markets respectively, measure the time required by the producer market (in the case of  $\lambda^s$ ) or the consumer for ( $\lambda^c$ ) to correct half of the deviations from equilibrium.

From the estimates involving Po as the producer market,  $\alpha^s$ , the significant adjustment made by Po to correct deviations from equilibrium range from -0.070 (7%) to -0.080 (8%), averaging 0.073 (7.3%). The corresponding adjustment,  $\alpha^c$ , made by the consumer markets including Techiman<sup>6</sup> vary from -0.009 to 0.035. None of these are however significant. In addition, only the estimates for Po-Tamale (0.035) and Po-Techiman (0.025) have the correct sign. The estimated half-lives,  $\lambda^s$ , for the significant adjustment speeds by Po range from 8.31 semi-weeks for Po-Kumasi, the market pair with the highest speed of adjustment, to 9.55 semi-weeks for Po-Accra and Po-Tamale, which have the lowest adjustment speed. Note that the estimated half-lives make economic sense for only significant adjustment speeds; hence no half-life estimates exist for  $\lambda^c$  when Po is specified as the producer market under the standard VECM.

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<sup>6</sup> Whenever Po is considered a producer market, Techiman theoretically becomes a consumer market. The reverse is true.

**Table 4: Estimated Speeds of Price Transmission and Half-Lives in the Standard VECM**

| <i>Market Pair</i>                          | <i>Price Adjustment Parameters and Half-lives</i> |             |                      |              |
|---|---|-------------|----------------------|--------------|
|   | $\alpha^s$  | $\lambda^s$ | $\alpha^c$           | $\lambda^c$  |
| Po – Accra                                  | -0.070***<br>[-3.649]                             | 9.55        | -0.022<br>[-1.068]   | -            |
| Po – Kumasi                                 | -0.080***<br>[-4.006]                             | 8.31        | -0.009<br>[-0.474]   | -            |
| Po – Tamale                                 | -0.070***<br>[-3.763]                             | 9.55        | 0.035<br>[1.700]     | -            |
| Po – Techiman                               | -0.071***<br>[-3.682]                             | 9.41        | 0.025<br>[1.247]     | -            |
| <b>Aver. adjustment with Po<sup>7</sup></b> | <b>-0.073</b>                                     | <b>9.93</b> | <b>0.035</b>         |              |
| Techiman - Accra                            | -0.097***<br>[-3.361]                             | 6.79        | 0.094***<br>[3.213]  | 7.02         |
| Techiman - Kumasi                           | -0.141***<br>[-5.284]                             | 4.56        | 0.029<br>[1.166]     |              |
| Techiman - Tamale                           | -0.069***<br>[-3.658]                             | 9.69        | 0.066***<br>[3.190]  | 10.15        |
| Techiman - Po <sup>8</sup>                  | -0.011<br>[-1.247]                                | -           | 0.030 ***<br>[3.682] | 22.76        |
| <b>Aver. adjustment with Tech</b>           | <b>-0.102</b>                                     | <b>7.01</b> | <b>0.063</b>         | <b>13.93</b> |

The asterisks \*, \*\* and \*\*\* denote significance at the 10%, 5% and 1% level respectively. Half-lives, measured in semi-weeks, are only computed for significant speeds of price transmission (adjustment parameters).

When we specify Techiman as the producer market, then the significant estimated  $\alpha^s$  range from -0.069 (6.9%) to -0.141 (14.1%), averaging -0.102 (10.2%), with half-lives between 4.56 for Techiman-Kumasi and 9.69 for Techiman-Tamale. The significant adjustment,  $\alpha^c$ , by the consumer markets including Po (Navrongo as proxy), on the other hand range from 0.030 (3%) to 0.094 (9.4%) averaging 0.063 (6.3%) with associated half-lives between 7 and 22.76 semi-weeks.

<sup>7</sup> Though averages here have no econometric importance, they are computed here just for comparative purposes.

<sup>8</sup> Actual, physical direct flow of tomato between Techiman and Po does not really exist. Po is therefore “proxied” by Navrongo which is located near the border to Burkina-Faso when Techiman is the producer market.

The findings indicate that though dynamic price relationships do exist between Po in Burkina Faso and the Ghanaian tomato markets, the degree of price transmission is generally lower (about 7%) when the Burkina Faso market (Po) is the production centre than when tomato is locally produced in Techiman, in which case the speed of price transmission averages about 10%. This means when there is no border between producer-consumer market pairs, or were the border effect between the markets removed, the speed of price transmission would be expected to improve by about 3%. Similarly, price adjustment by the producer market to correct disequilibrium following shocks would be faster without border effects than with same. The evidence is that the time required to eliminate half of the market disequilibrium following shocks would reduce from 10 semi-weeks with Po as the producer market (5 weeks) to about 7 semi-weeks (3.5 weeks) when Techiman is the source of tomato supply to the marketing system.

We suspect that the higher adjustment speeds by both the producer markets with Kumasi – i.e. Po-Kumasi (0.080) and Techiman-Kumasi (0.141) – may be attributed to both distance and border effects. By removing the border, the dynamic interaction of the producer market price with the Kumasi price increases from 8% to 14%. Despite the fact that Accra is biggest tomato consuming market in Ghana and is expected, *ceteris paribus*, to exert the highest influence on price dynamics in the producer markets, Kumasi, the second largest consumer market in Ghana, appears to be playing this role because of its closer proximity to both producer markets than Accra (see Fig. 1).

There is also evidence to suggest, in line with Ihle et al 2010, that the producer market prices seem to adjust more significantly towards correcting disequilibrium than prices in the consumer markets. In fact, none of the consumer markets significantly error corrects when the source of supply is across the border in Po. This means the consumer markets are largely weakly exogenous – i.e. only future price dynamics in these markets are mostly significantly influenced by existing dynamics in the producer markets. Overall, the results however demonstrate that price adjustment processes that correct deviations from long-run equilibrium relationships are bidirectional, i.e. prices on both markets tend to respond to deviations from their common equilibrium more in the absence of a border between markets than they do when there is a border separating the markets.

### **5.2.2 Results of the Regime-Dependent VECM**

Even though the above results of the standard VECM paint a general picture of the nature of inter-market price dynamics with and without the international border between the markets under study, the standard VECM is limited in not being able to distinguish between the seasonally -dependent regimes of tomato supply to the marketing system. By accounting for the regime effects in the regime-dependent VECM, we may obtain further evidence to verify the border effects identified above. This is because, with the tomato supply sources to the markets under study switching seasonally, then estimating the VECM with the speeds of adjustments specified as regime-varying parameters may yield more economically interpretable results than those of the standard VECM. The results of the regime-dependent VECM are presented in Table 5. They provide evidence of significant speeds of price transmission in both the with- and without-border settings – i.e. under the Po and Techiman regimes respectively. The estimates are particularly high for Techiman as a producer market under the Techiman regime for Kumasi and Accra, the biggest tomato consuming markets in Ghana.



To differentiate between price adjustment by the producer and consumer markets in each pair and to also identify these price adjustment processes under the two regimes, we denote the adjustment speeds and their associated half-lives under the Po regime (regime 1) as  $\alpha_1^s$  and  $\alpha_1^c$ , and  $\lambda_1^s$  and  $\lambda_1^c$  respectively. Similarly, the respective estimated parameters under the Techiman regime (regime 2) are denoted as  $\alpha_2^s$  and  $\alpha_2^c$ , and  $\lambda_2^s$  and  $\lambda_2^c$ .

**Table 5: Price Adjustment Speeds and Half-Lives in the non-Burkina-Faso Regime**

| <i>Po Regime</i>          | <i>Price Adjustment Parameters and Half-lives</i> |               |                       |               |
|---------------------------|---|---------------|-----------------------|---------------|
| <i>Market Pair</i>        | $\alpha_1^s$                                      | $\lambda_1^s$ | $\alpha_1^c$          | $\lambda_1^c$ |
| Po – Accra                | -0.092**<br>[-2.570]                              | 7.18          | -0.051<br>[-1.730]    | -             |
| Po – Kumasi               | -0.060**<br>[-1.967]                              | 11.20         | -0.057***<br>[-3.123] | 11.81         |
| Po – Tamale               | -0.109***<br>[-3.147]                             | 6.00          | 0.046<br>[1.134]      | -             |
| Po - Techiman             | -0.092***<br>[-2.570]                             | 7.18          | 0.035<br>[1.434]      | -             |
| <b>Average Adjustment</b> | <b>-0.088</b>                                     | <b>8.89</b>   | <b>0.057</b>          | <b>11.81</b>  |
| <i>Techiman Regime</i>    | $\alpha_2^s$                                      | $\lambda_2^s$ | $\alpha_2^c$          | $\lambda_2^c$ |
| Techiman – Accra          | -0.151***<br>[-5.041]                             | 4.23          | 0.057**<br>[1.920]    | 11.81         |
| Techiman – Kumasi         | -0.138***<br>[-3.905]                             | 4.67          | 0.042<br>[1.285]      | -             |
| Techiman – Tamale         | -0.050***<br>[-3.031]                             | 13.51         | 0.064***<br>[3.603]   | 10.48         |
| Techiman - Po             | -0.016<br>[-1.797]                                | -             | 0.032***<br>[3.301]   | 21.31         |
| <b>Aver. Adjustment</b>   | <b>-0.113</b>                                     | <b>7.47</b>   | <b>0.051</b>          | <b>14.53</b>  |

The asterisks \*\* and \*\*\* denote significance at the 5% and 1% level respectively.

Half-lives, measured in semi-weeks, are only computed for significant speeds of price transmission (adjustment parameters). Student t-values are in the parenthesis.

The speed of price adjustment ( $\alpha_1^s$ ) by the producer market, namely Po, under the Po regime ranges from -0.060 (6%) to -0.109 (10.9%) averaging -0.088 (8.8%). Like under the standard VECM, the adjustment speeds by the consumer markets ( $\alpha_1^c$ ) that correct deviations from equilibrium under the Po regime show significance at the 1% for only Kumasi. This estimate, however, has the wrong sign and is not economically interpretable. The corresponding adjustment half-lives by the producer market ( $\lambda_1^s$ ) range from 6 to 11.20 semi-weeks, averaging 8.89 semi-weeks. Even though the half-life for the adjustment by Kumasi ( $\lambda_1^c$ ) has been computed to be 11.81 semi-weeks, like its corresponding speed of adjustment estimate, this value too does not have economic meaning.

Under the Techiman regime, the significant speeds of price transmission from the producer market ( $\alpha_2^s$ ) range from -0.050 (5%) to -0.151 (15.5%) averaging -0.113 (11.3%). Unlike under the Po regime, three of the consumer markets – Accra (0.057), Tamale (0.064) and Techiman (0.032) – now respond significantly with the expected sign to error correct towards equilibrium following shocks. The average consumer-market speed of transmission ( $\alpha_2^c$ ) is 0.051 (5.1%). The half-lives of price adjustment by the producer market (Techiman) under this regime range from 4.23 to 13.51 semi-weeks, averaging 7.47 semi-weeks. The half-lives of adjustment parameters associated with the consumer markets range from 10.48 to 21.31 semi-weeks, averaging 14.53 semi-weeks.

The results of the regime-dependent VECM tell us that differences in the speeds of price transmission across the two regimes exist. These differences result in principle from changes in shocks to fresh tomato prices following shifts in the source of tomato supply from a local producer market that is averagely nearer to and not separated from the consumer markets by a border, to a foreign producer market across a border and averagely further from especially the large consumer markets. Alternatively stated, the empirical results hint at the likelihood of border and distance as the major underlying factors affecting the rate of price transmission and the timeliness of price adjustment between the markets under study. The results are thus consistent with the nature of cross-border trade in the ECOWAS region.

As noted earlier, even though the ECOWAS protocol on trade excludes any form of trade restrictions on member countries, practical impediments to smooth arbitrage processes exist at the borders and partly mitigate the effects of the protocol. The results in this way are of high theoretical and practical relevance; they demonstrate the extent of the integration of tomato markets between Ghana and Burkina-Faso and in the ECOWAS trade block in general. This allows policy makers to adopt the necessary steps to promote cross-border trade in the sub-region.

## 6. Conclusion and Outlook

The results of the above analysis show that the semi-weekly prices of fresh tomato largely co-move over the period of the investigation. Overall, the net consumer markets under both the Burkina-Faso and non-Burkina-Faso regimes are weakly exogenous i.e. they either do not react at all or react weakly to deviations from their long-run equilibrium with the net producer markets. The net producer markets on the other hand exhibit stronger and significant response to deviations from this equilibrium. This weak exogeneity of the consumer market may be attributed to the use of market power by trader to create price

transmission asymmetry – the transmission of especially positive price changes at the farm gate to retail and consumer markets while withholding positive price changes in the consumer markets from reaching the farm gate.

It can also be concluded that an increase in geographic distance and presence of borders between markets appear to weaken, all other things being equal, the speed of price transmission between markets separated by the borders. This is because other determinants of price transmission viz. transaction costs will generally increase with distance, making arbitrage more costly and increasing the average time required to complete a transaction (Ihle et al, 2010). Also the crossing of borders by traders in low income countries usually involves formal (and sometimes informal) costs, as well as delays. This effect is suspected to be particularly important in the West Africa Sub-region due to high costs incurred by traders at borders, the cumbersome nature of customs procedures and little transparency and automation of such procedures.

In conclusion, some evidence of the link between international borders and distance on the one hand, and the speed of price transmission on the other has been obtained using prices of tomato at the production centre at Burkina-Faso with prices on Ghanaian tomato markets. These results suggest that though borders in West Africa do not completely curtail cross-border trade, price transmission and consequently market integration, it nevertheless weakens these processes. Whether the observed, reducing effects are solely border and distance dependent or whether other microdrivers including poor communication, marketing, transportation, exchange rate, language and other practical difficulties are involved, is however difficult to unravel.

What is clear from the findings is that more can be done to improve the speed of price transmission between Ghanaian and Burkina-Faso tomato markets. Such an improvement is necessary to ultimately lead to an enhanced welfare for tomato producers in both countries. A methodological improvement of this analysis would be to extend the geographic coverage to consider more markets in Burkina-Faso and Ghana. Including in such analysis other factors such as concessionary trade conditions, not reflected in the prices would be useful.

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